US Navy’s Rail Gun Secret

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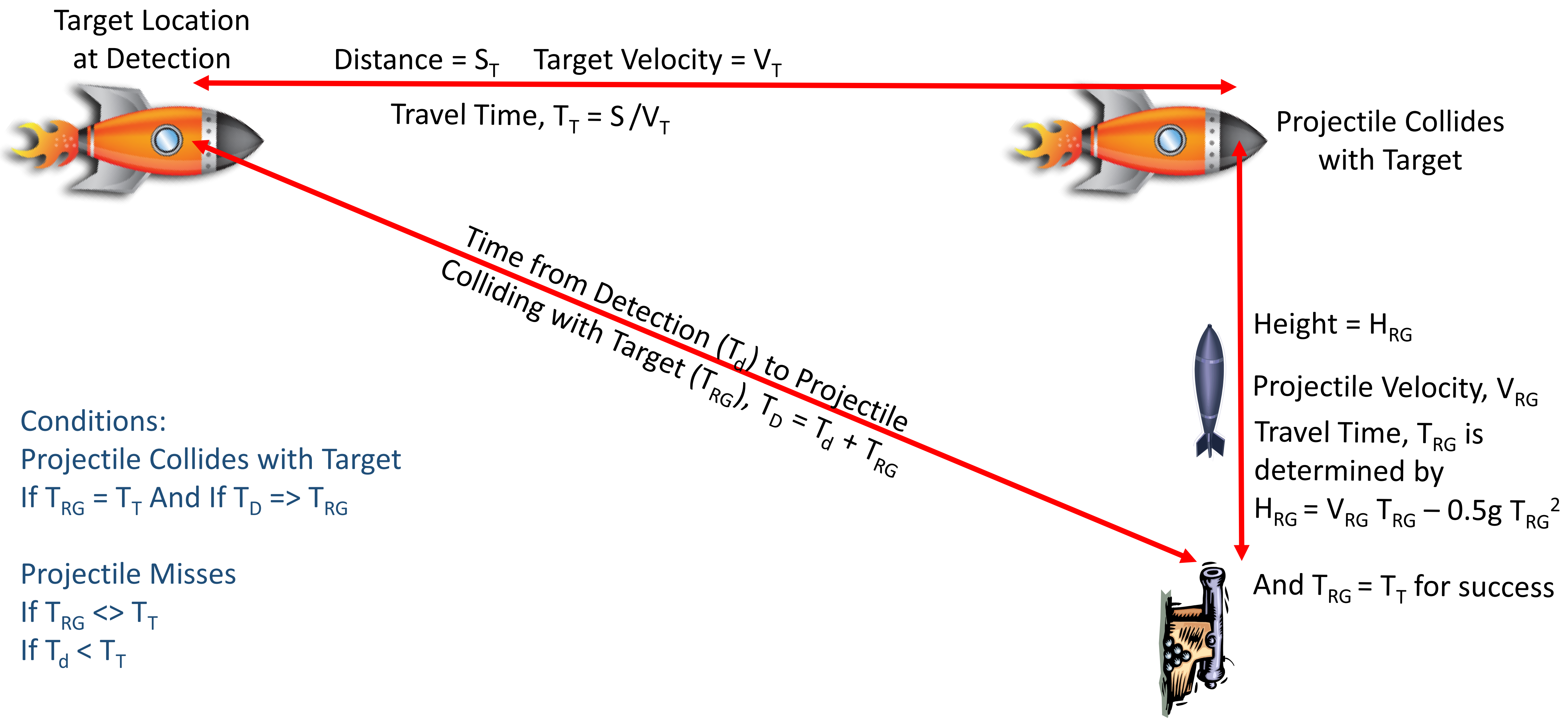
Problem Definition

The Problem Definition (1)



Conditions:

Projectile Collides with Target

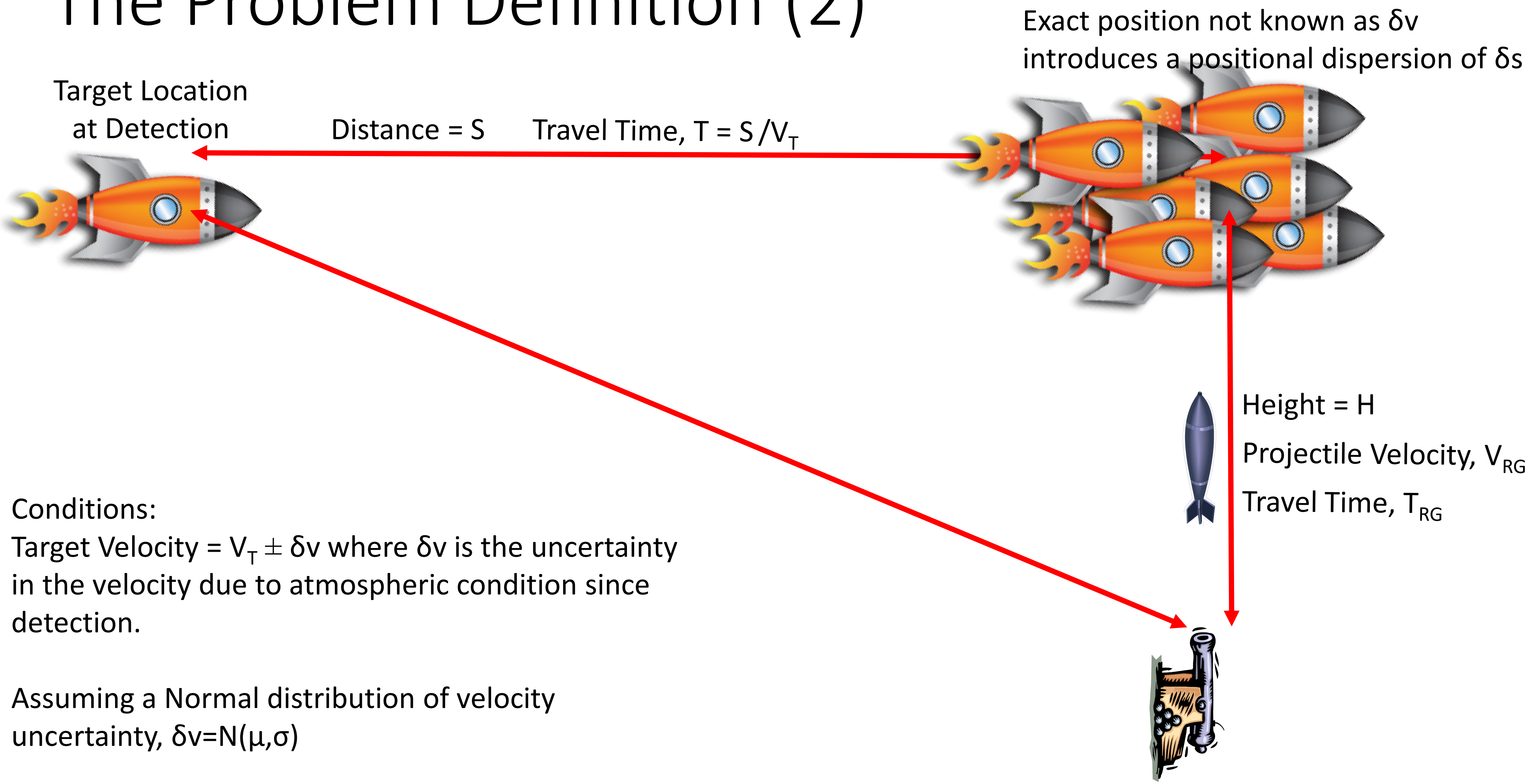
If $T_{RG} = T_T$ And If $T_D => T_{RG}$

Projectile Misses

If $T_{RG} <> T_T$

If $T_d < T_T$

The Problem Definition (2)



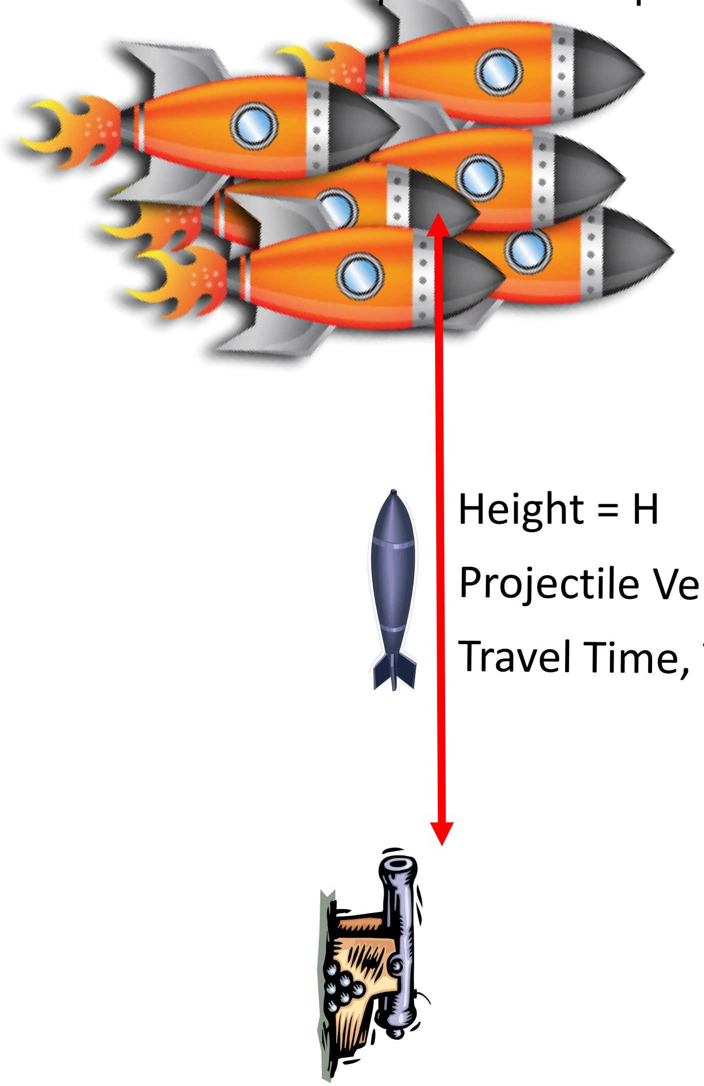
Conditions:
Target Velocity = $V_T \pm \delta v$ where δv is the uncertainty in the velocity due to atmospheric condition since detection.

Assuming a Normal distribution of velocity uncertainty, $\delta v = N(\mu, \sigma)$

The Problem Definition (3)

Problem:
Given that atmospheric conditions introduce $\pm\ \delta v$ what is the most likely position of the Target when the Projectile arrives at anticipated Target position?

Exact position not known as δv introduces a positional dispersion of δs



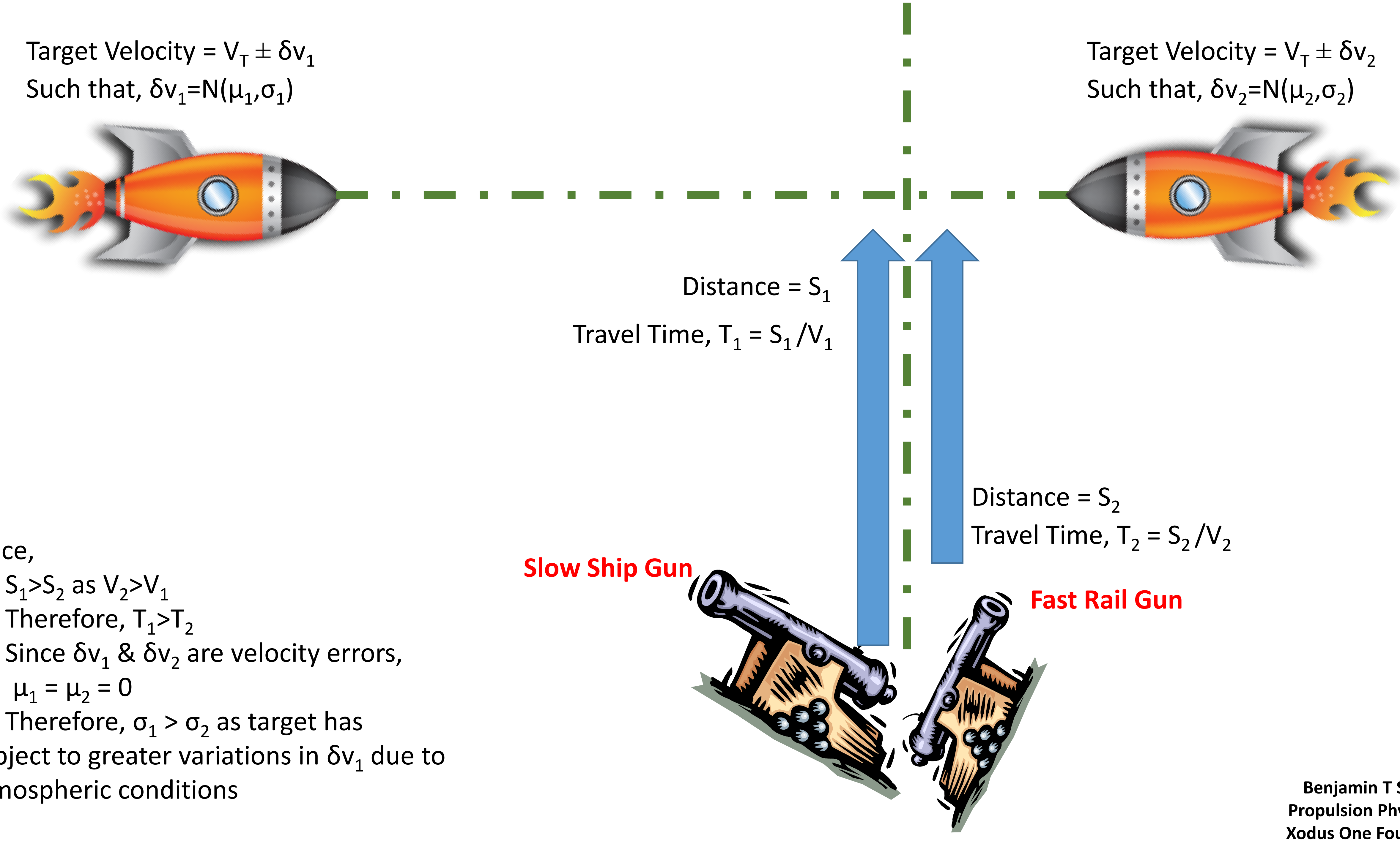
Height = H

Projectile Velocity, V_{RG}

Travel Time, T_{RG}

Conditions:
Given that, $\delta v = N(\mu,\sigma)$
Variation in the true anticipated Target Location, $\delta s = 6T_T\sigma$

Solution Formulation



Since,

(1) $S_1 > S_2$ as $V_2 > V_1$

(2) Therefore, $T_1 > T_2$

(3) Since δv_1 & δv_2 are velocity errors,

$\mu_1 = \mu_2 = 0$

(4) Therefore, $\sigma_1 > \sigma_2$ as target has subject to greater variations in δv_1 due to atmospheric conditions

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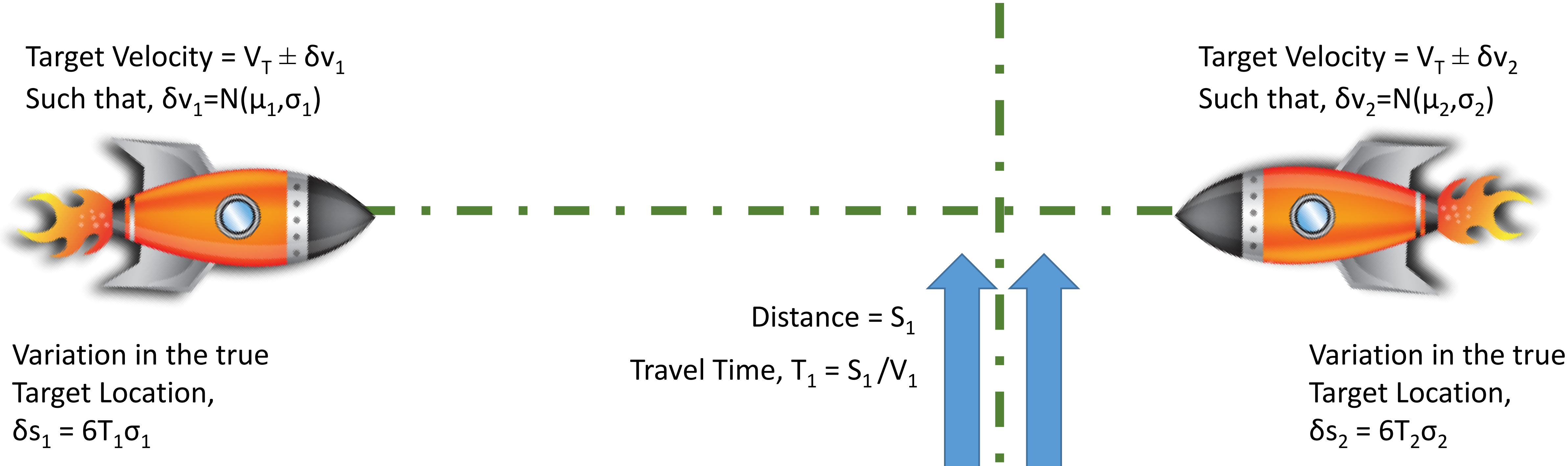

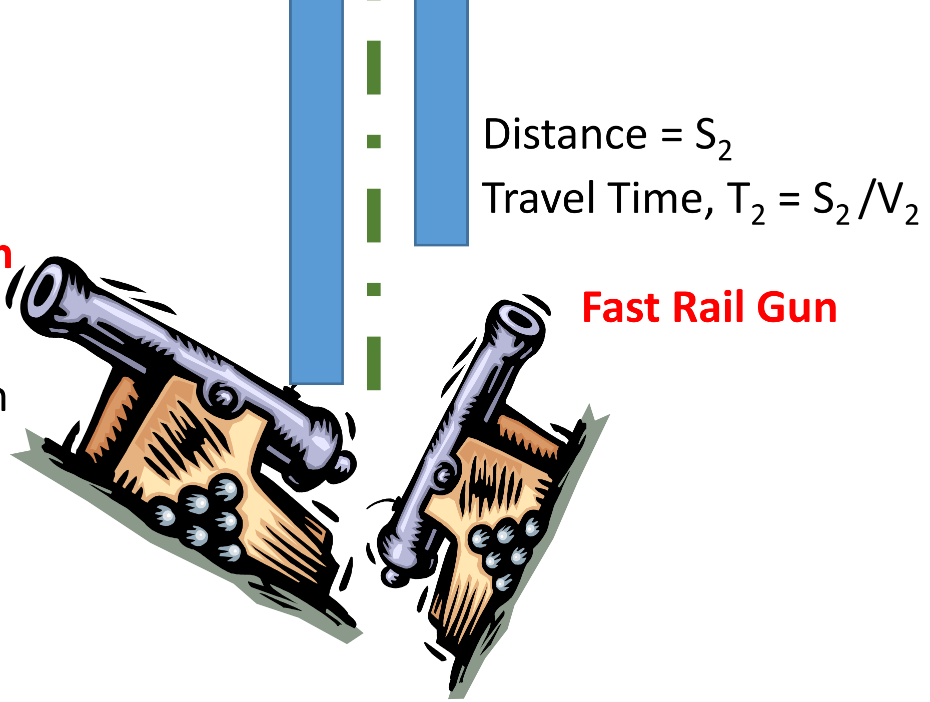

Since,

(1) $T_1 > T_2$

(2) $\sigma_1 > \sigma_2$

(3) Therefore, $6T_1\sigma_1 >> 6T_2\sigma_2$

(4) Or $\delta s_1 >> \delta s_2$

(5) To consistently hit a projectile we require that the variation in the Target Location $\delta s <$ Target Length

Summary: The faster the projectile muzzle velocity, V_R, the greater the accuracy & therefore the probability of hitting the moving target.

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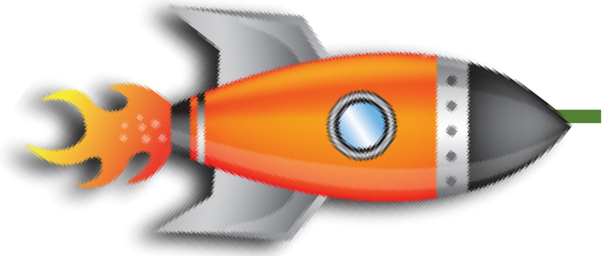
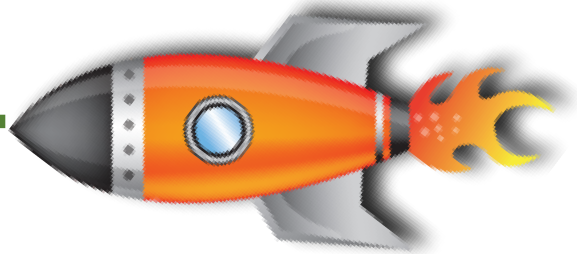
Target Velocity = $V_T \pm \delta v_1$
Such that, $\delta v_1 = N(\mu_1, \sigma_1)$



Variation in the true Target Location,
$\delta s_1 = 6T_1\sigma_1$

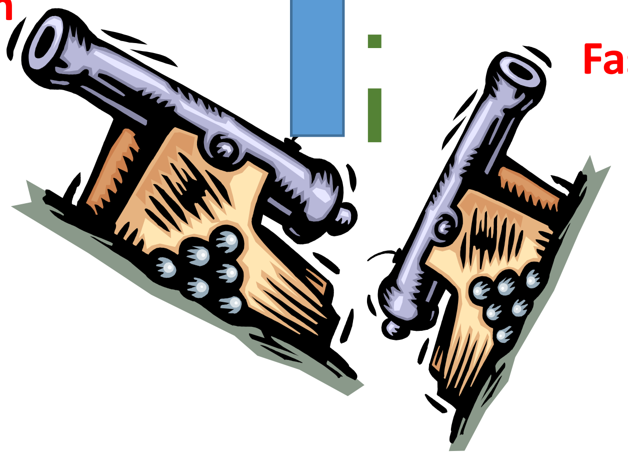
Target Velocity = $V_T \pm \delta v_2$
Such that, $\delta v_2 = N(\mu_2, \sigma_2)$



Variation in the true Target Location,
$\delta s_2 = 6T_2\sigma_2$

Distance = S_1
Travel Time, $T_1 = S_1 / V_1$

Distance = S_2
Travel Time, $T_2 = S_2 / V_2$



For simplicity, if we assume that the increase in the spread is a function of time, such that

(1) $\sigma_1 = k.T_1$ and $\sigma_2 = k.T_2$ where k is some constant
(2) Then $\delta s_1 = 6kT_1^2$ and $\delta s_2 = 6kT_2^2$
(3) Or $\delta s_2 / \delta s_1 = (T_2/T_1)^2 = (S_2/S_1)^2.(V_1/V_2)^2$
(4) Or upper bound of $\delta s_2 / \delta s_1 \approx (V_1/V_2)^2$

Conclusion: Hit accuracy is geometrically dependent upon projectile muzzle velocity, V_R.

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Real Examples

Rail Gun versus Mark 80 Projectile

Comparisons	Muzzle Velocity (MPH)
Rail Gun	5,600
Mark 80 projectile with Mark 67 cartridge	831
Mark 80 projectile with EX-175 cartridge	1,052

Target Location Spread	Mark 80 projectile with Mark 67 cartridge	Mark 80 projectile with EX-175 cartridge
Rail Gun / Mark 80 ($\delta s2$ / $\delta s1 \approx (V1/V2)^2$)	2.2%	3.5%

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X-51 : The Reverse is True

- With the Air Force's X-51 scram jet:
  - Capable of Mach 5 or 3,800 mph.
  - Cruising altitude of 70,000 ft.
  - Length of 25 ft.

- Target location spread is $\delta s_1 = 6T_1\sigma_1$. Using the above data for a rail gun projectile, gives an upper limit of σ=0.3 mph for δs_1 = 25 ft.
- The table below shows a projectile traveling at less than the velocity of the X-51 does not have the accuracy to shoot down the X-51.

Projectile Velocity (mph)	5,000	4,000	3,000	2,000	1,000
(Mach)	6.6	5.3	3.9	2.6	1.3
% of X-51 Velocity	132%	105%	79%	53%	26%
δs (ft)	19	24	31	43	70

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We can thank the late
Prof. Eric Laithwaite
for the rail gun.

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Important Lessons to Take Away

- Technology ≠ Key Strategic Value
  - Key strategic value = Substantially improved accuracy
  - Deliverer of value = Substantially increased velocity
  - Mechanism to attain Delivery = The new technology of the Rail Gun

  - Key strategic value is loosely coupled to the new technology
    - Therefore, potential for other types of technologies to replace rail gun

- High velocity is a substitute for missile guidance systems